# Diagnosis of pancreatic cancer by 2[$^{18}$F]-fluoro-2-deoxy-D-glucose positron emission tomography

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**Abstract**

**The detection of pancreatic cancer or the discrimination between pancreatic cancer and chronic pancreatitis remains an important diagnostic problem. The increased glucose metabolism in malignant tumours formed the basis for this investigation, which focused on the role of positron emission tomography (PET) with 2[$^{18}$F]-fluoro-2-deoxy-D-glucose (FDG) in the detection of pancreatic cancer and its differentiation from chronic pancreatitis. Eighty patients admitted for elective pancreatic surgery received preoperatively 250–350 mBq FDG intravenously and emission scans were recorded 45 minutes later. Intense focal activity in the pancreatic region was taken at the time of scanning as showing the presence of pancreatic cancer. The presence of cancer was later confirmed by histological examination of the surgical specimens and histological findings were compared with the preoperative PET results. Forty one patients with pancreatic cancer (group I: n=42) had a focally increased FDG uptake in the pancreatic region. Two patients with a periampullary carcinoma (group II: n=6) failed to develop FDG accumulation. In 28 patients with chronic pancreatitis (group III: n=32) no FDG accumulation occurred. Overall sensitivity and specificity of PET for malignancy (group I+II) were 94% (45 of 48) and 88% (28 of 32), respectively. The standard uptake value of the patients with pancreatic carcinoma was significantly higher than in patients with chronic pancreatitis (3·09 (2·18) *v* 0·87 (0·56); p<0·001; median (interquartile range)). These findings show that FDG-PET represents a new and non-invasive diagnostic procedure for the diagnosis of pancreatic cancer and to differentiate pancreatic cancer from chronic pancreatitis. However, the diagnostic potential of this technique requires further evaluation.**

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Among gastrointestinal cancers, pancreatic carcinoma has the worst prognosis: less than 20% of affected patients survive the first year after diagnosis. This poor outcome may result from the frequent late diagnosis of the disease when it has reached stages III or IV, and the tumour has spread to lymph nodes or distant metastases, or both are already present.[1–3]

Diagnosis of pancreatic cancer may be difficult, as clinical symptoms are rather unspecific and non-invasive imaging methods such as ultrasonography or contrast enhanced computed axial tomography (CAT) only detect indirect signs of the tumour such as a pancreatic mass or ductal abnormalities.

Positron emission tomography (PET) has recently been developed as a non-invasive imaging method for tissue characterisation based more on specific tissue metabolism rather than on imaging tissue mass, contour, echogeniety or *x* ray absorption. Thus, increased glucose utilisation, a metabolic hallmark of many malignant tumours,[4] has been used for non-invasive identification of malignant primary or recurrent colorectal cancer, as well as cancer in the lung, head, neck, and brain.[5–10] In these studies the glucose analogue 2[$^{18}$F]-fluoro-2-deoxy-D-glucose (FDG) has been used to measure overall tumour glucose utilisation with PET.[11]

In pancreatic disorders, PET with $^{11}$C-labelled L-methionine cannot distinguish pancreatic cancer from chronic pancreatitis.[12] In contrast, previous studies show that FDG-PET seems to have a higher accuracy in the diagnosis of pancreatic cancer and to be effective in the differentiation of cancer from chronic inflammation.[13 14] In addition, a general increase in the expression of genes associated with the inward transport of glucose and glycolysis has been shown in pancreatic adenocarcinoma.[12–14] In this study we examined prospectively the performance of FDG-PET in the diagnosis of pancreatic cancer and assess the ability of the technique to differentiate pancreatic carcinoma from chronic pancreatitis in 80 consecutive patients undergoing elective pancreatic surgery.

## Methods

*Study protocol*

The investigation was designed as a blind study (a) to evaluate the ability of FDG-PET to confirm the presence of cancer in patients with histologically confirmed pancreatic cancer (sensitivity) and (b) to define its specificity in patients with histological confirmed chronic pancreatitis. All patients were admitted to our hospital for elective pancreatic surgery and only those who gave written informed consent

TABLE I *Patient characteristics, tumour localisation, tumour stage, standard uptake value (SUV), tumour background ratio (T/B), and operative procedures in 42 patients with histological confirmed pancreatic cancer (patients 1–42) and six patients with histologically confirmed periampullary cancer (PC) (patients 43–48)*

| *Patient* | *Sex* | *Age* | *Localisation* | *Stage* | *CAT* | *PET* | *SUV* | *T/B* | *FDG accumulation* | *Operation* |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | M | 78 | Head | III | + | + | 4·70 | 11·81 | Head | Whipple |
| 2 | M | 68 | Head | II | + | − | 3·91 | 7·90 | Negative | Local recurrence after Whipple |
| 3 | M | 55 | Head | IV | + | + | 1·20 | 3·98 | Head | Biliary bypass |
| 4 | M | 62 | Head | II | + | + | 2·22 | 5·57 | Body | Local recurrence after Whipple |
| 5 | M | 55 | Head | IV | + | + | 4·20 | 5·14 | Body, liver | Local recurrence after Whipple |
| 6 | M | 63 | Body | IV | + | + | 3·26 | 7·78 | Body, lymph node | Laparotomy |
| 7 | F | 73 | Body | IV | − | + | 3·35 | 7·43 | Body | Laparotomy |
| 8 | F | 63 | Head | IV | + | + | 5·65 | 21·27 | Head, liver | Needle biopsy |
| 9 | M | 64 | Head | III | + | + | 0·98 | 1·41 | Head | Whipple |
| 10 | F | 51 | Head | III | − | + | 2·11 | 4·09 | Head | Whipple |
| 11 | M | 50 | Head | IV | + | + | 3·16 | 3·60 | Head, liver | Laparoscopy |
| 12 | M | 50 | Head | III | + | + | 1·41 | 10·54 | Head | Local recurrence after Whipple |
| 13 | F | 52 | Head | III | + | + | 2·88 | 7·28 | Head | Laparotomy |
| 14 | M | 58 | Head | III | − | + | 1·54 | 3·10 | Hepatic porta | Local recurrence after Whipple |
| 15 | M | 71 | Head | IV | + | + | 1·19 | 2·67 | Liver | Local recurrence after Whipple |
| 16 | F | 55 | Head | III | + | + | 4·11 | 10·22 | Head | Whipple |
| 17 | M | 67 | Head | IV | − | + | 3·78 | 11·99 | Head | Biliary and enteral bypass |
| 18 | M | 59 | Head | II | + | + | 1·78 | 4·06 | Pancreas | Whipple |
| 19 | F | 62 | Body | IV | + | + | 2·41 | 4·43 | Head | Laparotomy |
| 20 | F | 66 | Head | IV | + | + | 5·22 | 16·30 | Head | Whipple |
| 21 | M | 79 | Tail | IV | + | + | 1·98 | 3·94 | Tail | Laparoscopy |
| 22 | M | 52 | Body | IV | + | + | 2·48 | 5·84 | Head, liver | Laparotomy |
| 23 | F | 69 | Head | III | + | + | 4·18 | 13·71 | Head | Whipple |
| 24 | M | 64 | Head | IV | + | + | 3·03 | 8·63 | Head, liver | Biliary bypass |
| 25 | M | 52 | Head | III | + | + | 2·00 | 5·40 | Head | Whipple |
| 26 | M | 50 | Head | IV | + | + | 5·52 | 14·58 | Head | Whipple |
| 27 | M | 58 | Head | II | − | + | 2·76 | 7·36 | Head | Whipple |
| 28 | M | 61 | Head | III | + | + | 1·44 | 5·50 | Head | Whipple |
| 29 | M | 64 | Head | III | + | + | 5·71 | 15·20 | Head | Whipple |
| 30 | M | 64 | Head | III | + | + | 0·85 | 2·10 | Head | Whipple |
| 31 | M | 52 | Head | III | + | + | 3·65 | 8·28 | Head | Whipple |
| 32 | M | 36 | Head | IV | − | + | 7·70 | 22·66 | Head | Laparotomy |
| 33 | F | 62 | Head | III | + | + | 2·29 | 4·88 | Head | Whipple |
| 34 | F | 55 | Head | IV | − | + | 5·66 | 10·86 | Head | Biliary bypass |
| 35 | F | 46 | Head | II | − | + | 1·27 | 2·19 | Head | Whipple |
| 36 | M | 62 | Head | IV | + | + | 3·45 | 8·80 | Head, liver | Biliary bypass |
| 37 | M | 58 | Tail | III | + | + | 3·47 | 8·52 | Tail | Left resection |
| 38 | M | 57 | Head | III | + | + | 2·38 | 6·34 | Head | Whipple |
| 39 | M | 60 | Head | III | + | + | 7·24 | 12·00 | Head | Whipple |
| 40 | M | 66 | Head | III | + | + | 4·70 | 12·20 | Head | Whipple |
| 41 | M | 52 | Body | III | + | + | 3·33 | 5·64 | Body | Laparotomy |
| 42 | F | 74 | Head | II | − | + | 2·22 | 5·15 | Head | Laparotomy |
| 43 | M | 42 | PC | III | − | + | 1·53 | 10·37 | Head | Whipple |
| 44 | M | 64 | PC | III | + | + | 1·47 | 2·65 | Head | Whipple |
| 45 | F | 62 | PC | III | + | + | 2·74 | 6·52 | Head, lymph node | Whipple |
| 46 | F | 53 | PC | III | + | + | 6·45 | 15·59 | Head, lymph node | Cholecystectomy, lymph node dissection* |
| 47 | F | 76 | PC | I | − | − | 1·14 | 2·11 | Negative | Whipple |
| 48 | M | 55 | PC | II | − | − | 0·64 | 1·70 | Negative | Whipple |

*Whipple resection was not possible because of intraoperative tachyarhythmia and pulmonary insufficiency.
Whipple=Whipple's pancreatoduodenectomy. CAT: +=suspicious tumour mass with direct or indirect signs of malignancy, −=no pathological findings. PET: +=FDG accumulation in the tumour, suspicious for malignancy, −=no FDG accumulation in the tumour.

were included into this study. Staging of the pancreatic cancer was carried out according to the International Union against Cancer (UICC) classification.[18] All patients had either surgery of the pancreas with subsequent histological examination of the surgical specimen or diagnosis was obtained by intraoperative fine needle biopsies. In addition, follow up in patients with chronic pancreatitis (7–25 months) after pancreatic surgery did not disclose any false diagnosis. The histological diagnosis was compared with the preoperative PET results. In addition in all patients, CAT was performed between four and 14 days before surgery and the results were compared with PET and the histological diagnosis of the patients.

*Ethics*

The protocol was approved by the institutional review board of the University of Ulm (human ethics committee). Informed written consent was obtained from each participant.

*Patients*

Eighty patients entered the prospective trial between February 1992 and November 1993.

*Group I* – 42 patients (30 male, 12 female, median age: 60·5 years, range: 36–79) with pancreatic ductal cancer histologically confirmed at the time of surgery (Table I, patients no 1–42). The stages according to the UICC scale were: stage II: six patients, stage III: 19 patients, stage IV: 17 patients.

*Group II* – six patients (three male, three female, median age: 58·5 years, range: 42–76) with periampullary cancer histologically confirmed at the time of surgery (Table I, patients no 43–48). The UICC stages were: stage I: one patient, stage II: one patient, stage III: four patients.

*Group III* – 32 patients (27 male, five female, median age: 50 years, range: 25–74) with chronic pancreatitis histologically confirmed at the time of surgery (Table II).

*Normal controls* – 10 patients (six male, four female, median age: 51·5 years, range: 29–71) without gastrointestinal disease.

*Radiopharmaceutical*

FDG was synthesised according to the procedure described elsewhere.[19] The

TABLE II *Patient characteristics, standard uptake value (SUV), tumour background ratio (T/B), and operative procedures in 32 patients with histologically confirmed chronic pancreatitis*

| *Patient* | *Sex* | *Age* | *CAT* | *PET* | *SUV* | *T/B* | *FDG accumulation* | *Operation* |
|---|---|---|---|---|---|---|---|---|
| 1 | M | 42 | − | − | 0·76 | 2·07 | Negative | Cystojejunostomy |
| 2 | M | 44 | − | − | 0·69 | 1·87 | Negative | Necrosectomy, cholecystectomy |
| 3 | F | 52 | − | − | 0·83 | 1·68 | Negative | DPPHR |
| 4 | M | 54 | + | − | 0·68 | 1·13 | Negative | Whipple |
| 5 | M | 38 | + | − | 0·73 | 1·57 | Negative | Laparotomy |
| 6 | M | 48 | − | − | 1·29 | 1·79 | Negative | DPPHR |
| 7 | M | 56 | − | + | 1·14 | 8·00 | Head | Whipple |
| 8 | M | 53 | + | − | 1·77 | 2·20 | Negative | Whipple |
| 9 | M | 44 | − | − | 1·20 | 3·06 | Negative | DPPHR |
| 10 | M | 37 | + | − | 0·83 | 3·21 | Negative | DPPHR |
| 11 | M | 49 | − | + | 2·29 | 3·89 | Head | DPPHR |
| 12 | M | 51 | − | − | 0·85 | 2·33 | Negative | Necrosectomy |
| 13 | M | 63 | − | − | 0·80 | 2·35 | Negative | DPPHR |
| 14 | F | 39 | − | − | 0·99 | 3·59 | Negative | Cholecystectomy (gall stones) |
| 15 | M | 31 | − | − | 1·25 | 3·30 | Negative | Whipple |
| 16 | F | 60 | + | + | 3·33 | 9·36 | Head | Whipple |
| 17 | M | 36 | − | − | 0·65 | 1·43 | Negative | DPPHR |
| 18 | M | 66 | + | − | 1·01 | 2·43 | Negative | Left resection |
| 19 | M | 56 | − | − | 0·69 | 1·13 | Negative | DPPHR |
| 20 | M | 64 | − | + | 1·93 | 4·13 | Head, liver | DPPHR |
| 21 | M | 35 | − | − | 0·88 | 1·70 | Negative | DPPHR |
| 22 | M | 54 | + | − | 0·75 | 2·78 | Negative | Whipple |
| 23 | M | 34 | − | − | 0·79 | 2·30 | Negative | Whipple |
| 24 | M | 56 | − | − | 1·98 | 7·80 | Negative | Whipple |
| 25 | M | 25 | + | − | 0·37 | 1·50 | Negative | Whipple |
| 26 | M | 47 | − | − | 1·51 | 3·99 | Negative | DPPHR |
| 27 | M | 58 | − | − | 0·90 | 2·10 | Negative | DPPHR |
| 28 | M | 59 | − | − | 1·23 | 2·19 | Negative | DPPHR |
| 29 | M | 40 | − | − | 0·70 | 1·89 | Negative | DPPHR |
| 30 | F | 74 | + | − | 1·36 | 1·50 | Negative | Laparotomy |
| 31 | M | 38 | + | − | 0·69 | 2·77 | Negative | Whipple |
| 32 | F | 53 | − | − | 0·46 | 1·70 | Negative | DPPHR |

DPPHR=duodenum preserving pancreatic head resection. Other abbreviations as Table I.

radiochemical purity was 98·5%±(0·7%), the specific activity was > than 10 000 Ci/mmol at the end of synthesis. Patients were injected 250–350 mBq within four hours of FDG synthesis.

*Patient examination*

PET was performed using an ECAT 931-08 scanner (Siemens-CTI, Knoxville, TN, USA), which produces 15 contiguous slices (slice thickness of 6·7 mm for both primary and secondary slices) per bed position.

Patients were fasted for at least six hours before the study. Emission scans were performed in three bed positions covering a field of view of 31·5 cm. The position of the pancreas was confirmed by ultrasonographic localisation. By scanning 31·5 cm downwards from the liver dome the pancreatic bed was always located in the scanning area.

After transmission scanning with a Ge-68/Ga-68 ring source, 250–350 mBq FDG was injected into an antecubital vein and flushed with 10 ml saline. The patient was injected intravenously with furosemide (20 mg) and was instructed to urinate as often as possible to avoid unnecessary exposure of the bladder and to reduce measurement artifacts caused by high radioactivity in the urinary system. In preliminary studies without diuretic treatment, FDG contaminated urine in the urinary system was found in most cases to reduce image quality and analysis (data not shown). The patients had to leave the measurement area to urinate. Upon return they were carefully repositioned in the gantry using laser supported markings. We estimate that this led to a misalignment of maximum 1 cm in all directions, which in turn would cause an error of ±20% in the calculation of the standard uptake value (see later) assuming a change of 2 cm in the diameter of the target volume. Forty five minutes after FDG administration, emission scans were recorded for 10 minutes. Transmission scans were recorded to permit correction for photon attenuation. The acquisition time was 10 minutes per bed position and the count rate was 200 000±15% per second, resulting in a total of 120 000 000±15% counts (random and scatter corrected true counts per acquisition).

Image reconstruction was performed by an iterative reconstruction algorithm modified according to Schmidlin *et al.*[20] The actual resolution was 7 mm for iterative reconstruction for full width at half maximum at the centre of the field of view.

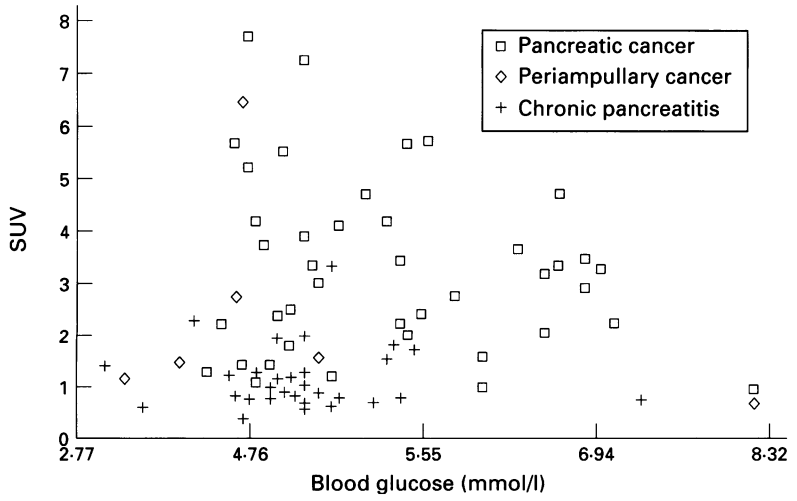


*Figure 1: Influence of plasma glucose concentrations on FDG standard uptake values (SUV) in 42 patients with pancreatic cancer, six patients with periampullary carcinoma, and 32 patients with chronic pancreatitis. Values for two patients with chronic pancreatitis (blood glucose 16·1 mmol/l, SUV 1·29; blood glucose 11·6 mmol/l, SUV 0·68), and one pancreatic cancer patient (blood glucose 12·1 mmol/l, SUV 2·29) are not shown.*

TABLE III *Standard uptake values (SUV) and tumour background ratio (T/B) in the pancreas and the liver of pancreatic cancer patients depending on blood glucose concentrations*

| Blood glucose | | >6·66 mg/100 ml (n=8) | <6·66 mg/100 ml (n=34) | Mann-Whitney U test |
|---|---|---|---|---|
| Pancreas | (SUV) | 3·07 (1·15) | 3·10 (2·22) | NS |
| | (T/B) | 6·46 (2·93) | 7·39 (7·72) | NS |
| Liver | (SUV) | 1·27 (0·42) | 1·41 (0·38) | NS |
| | (T/B) | 2·78 (1·08) | 3·27 (1·30) | NS |

Values are median (interquartile range), NS=not significant.

Images of the transversal, coronal, and sagital image slices were evaluated by two independent observers who had no prior knowledge of the patients' clinical status. Pancreatic cancer was assumed if an intense focal activity accumulation was detected in the pancreatic region that exceeded the activity concentration in the liver.

Circular regions of interest were drawn on (a) the 'hot spots' of the pancreas, (b) corresponding regions of the head of the pancreas in patients without focal pancreatic activity, and (c) control regions. The size of the region of interests was 1500 (350) (mean (SD)) pixels. FDG accumulation was calculated using the standard uptake value:

$$\text{standard uptake value} = \frac{\text{activity concentration in region of intetest} \times \text{body weight}}{\text{injected dose}}$$

Additional control regions (321 pixels) in the autochtonic skeletal muscle group of the back were chosen for the calculation of tumour/background ratios.

*Statistics*

The data are presented as median and interquartile range (median (interquartile range)). Blood glucose, standard uptake values, and tumour/background ratios of patients with pancreatic cancer and chronic pancreatitis were compared using the Mann-Whitney U test. Differences between proportions were analysed by the $\chi^2$ test. Differences were considered statistically significant when p was $<0{\cdot}05$.

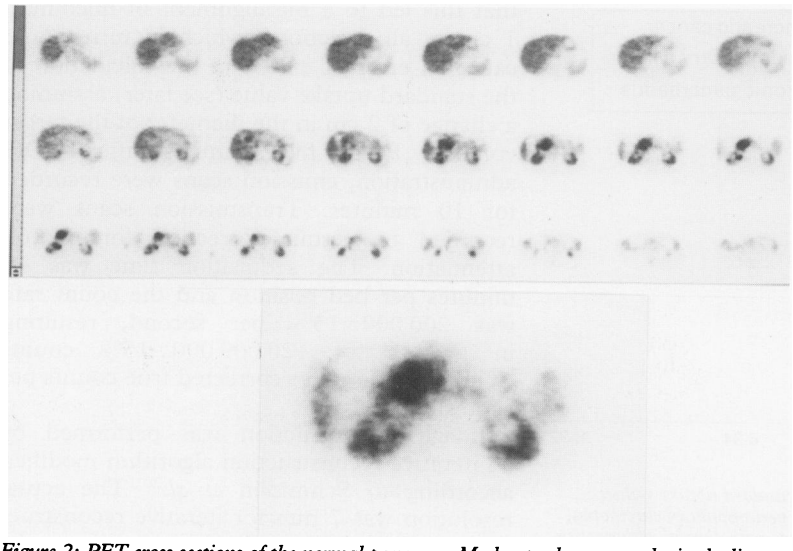

*Figure 2: PET cross sections of the normal pancreas. Moderate glucose uptake in the liver, the renal parenchyma, and the urinary collecting system can be seen.*

## Results

All 80 patients of groups I to III had surgery eight days (range 1–54) after FDG-PET imaging. Median blood glucose concentrations were 5·19 (interquartile range: 1·94), 4·67 (interquartile range: 1·19), and 4·78 (interquartile range: 1·11) mmol/l, respectively in groups I, II, or III. No correlation between FDG uptake (as assessed by standard uptake value) and tumour/background ratio with plasma glucose concentrations were found (Fig 1).[21] Blood glucose concentrations were obtained at the time of FDG injection in all patients. In eight of 42 patients with pancreatic cancer, the blood glucose concentrations exceeded 6·66 mmol/l. None of these patients, however, was false negative judged by visual analysis. Although all FDG uptake values were lower in a small group of patients with raised serum glucose concentrations, these differences were not significant (Table III).

*Imaging*

High quality FDG-PET images of the upper abdomen were obtained using the iterative reconstruction approach for imaging generation.[20] As known from previous PET studies in patients with various non-pancreatic cancers, glucose utilisation in the normal pancreas is very low in the fasting state and comparable with soft tissue background. As Fig 2 shows, the normal pancreas is not visualised by FDG-PET. There is moderate glucose uptake in the liver and some FDG uptake in the renal parenchyma and in the urinary collecting system. Using furosemide, FDG retention in the urinary system could be considerably reduced, thus improving image quality considerably (data not shown).

*Qualitative evaluation*

Figure 3 shows a typical FDG-PET image in a patient with pancreatic adenocarcinoma and stage III disease. The pancreatic mass noted in CAT had greatly increased FDG uptake. Similarly 41 of 42 patients with pancreatic cancer (group I) had a focally increased FDG uptake, amounting to a PET sensitivity of 98% for pancreatic cancer detection. The median standard uptake value was 3·09 (interquartile range: 2·18) in this group of patients (Fig 4, Table IV). The median standard uptake value was significantly higher than in group III (3·09 versus 0·87, $p<0{\cdot}001$) (Fig 4, Table IV). Four of six patients with periampullary cancer were positive as judged by FDG-PET. Taking the cancer patients together the sensitivity was 94% (45 of 48). All patients with stage III and IV (pancreatic cancer and periampullary cancer) showed focally increased FDG accumulation in PET, compared with five of eight patients (63%) with stages I and II disease.

In 28 of 32 patients suffering from chronic pancreatitis, the pancreas was not visualised by FDG-PET, giving a specificity of 88% for a malignant lesion. The median standard uptake

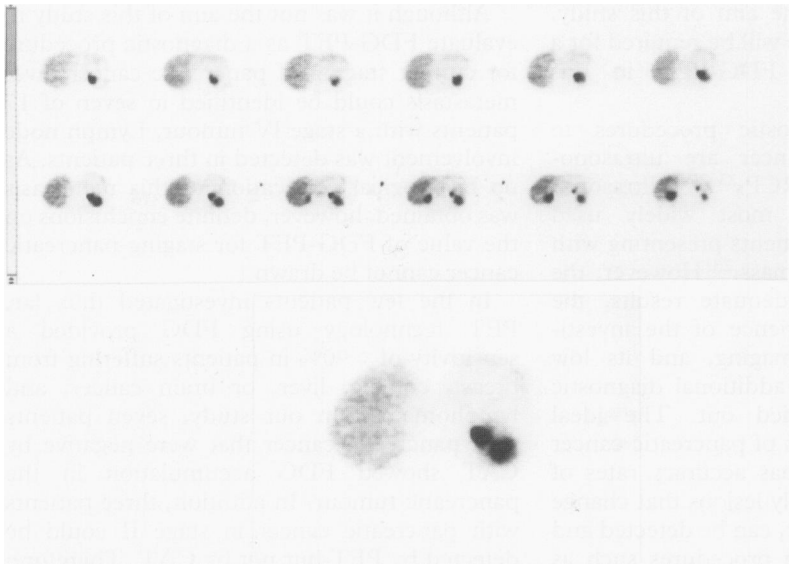

*Figure 3: PET cross sections in a patient with pancreatic cancer. Increase of FDG uptake in the malignant pancreatic tumour can be seen.*

value in chronic pancreatitis was 0·87 (interquartile range: 0·56). Of the patients with chronic pancreatitis who showed focally increased FDG uptake in the pancreatic head, one had received a nasobiliary probe to release common bile duct obstruction before FDG-PET. In a second patient BII resection had been performed 29 years previously. In addition, this patient had thrombosis of the portal vein with venous hypertension. In the third patient haemorrhage in a pancreatic pseudocyst was detected. The fourth patient had chronic pancreatitis without specific additional lesions or complications.

The positive and negative predictive values of FDG-PET were 91% and 98%, respectively.

*Quantitative evaluation*

Tumour/background ratios correlated highly with the corresponding standard uptake values ($r$=0·89, p<0·001). The difference between the basic standard uptake value and the tumour/background ratios in patients of group I (pancreatic cancer) and group II (periampullary carcinoma) versus group III (chronic pancreatitis) was statistically significant (p<0·001).

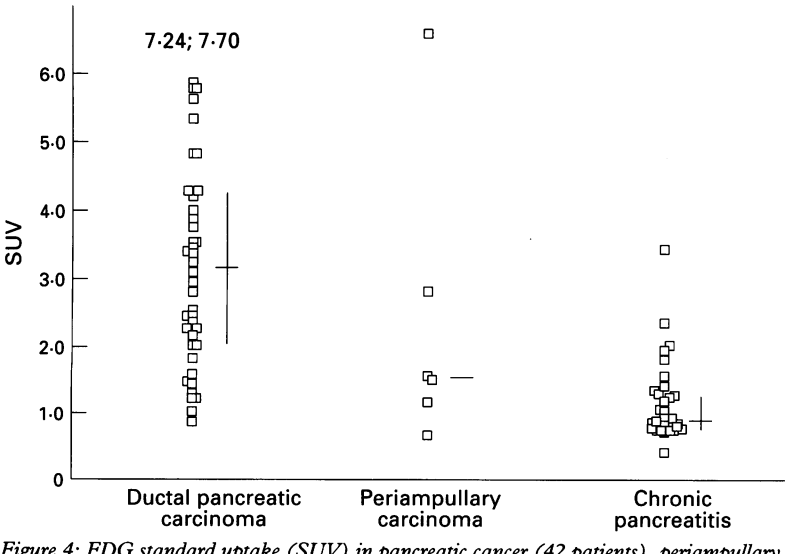


*Figure 4: FDG standard uptake (SUV) in pancreatic cancer (42 patients), periampullary cancer (six patients), and chronic pancreatitis (32 patients). SUV of patients with pancreatic cancer were significantly higher than in patients with chronic pancreatitis (p<0·001). Horizontal bar=median, vertical bar=interquartile range.*

TABLE IV *Standard uptake values in the pancreas and the liver of patients with pancreatic cancer, chronic pancreatitis, and normal controls*

| | *Pancreatic cancer (n=42)* | *Chronic pancreatitis (n=32)* | *Normal controls (n=10)* |
|---|---|---|---|
| Pancreas | 3·09 (2·18) | 0·87 (0·56) | 0·73 (1·02) |
| Liver | 1·38 (0·40) | 1·25 (0·52) | 1·27 (1·51) |

Values are median (interquartile range).

*Diagnostic accuracy of CAT*

Analysis of CAT for diagnosis of pancreatic cancer, performed in all patients preoperatively, yielded a sensitivity and specificity of 79% (33 of 42) and 69% (22 of 32), respectively.

Tumour stages I and II were present in two patients with periampullary carcinoma and six patients with pancreatic cancer. A suspicious tumour mass was detectable by CAT in three of these patients (38%). $\chi^2$ analysis showed that PET had a significant higher sensitivity for pancreatic cancer detection than CAT (p<0·01).

The positive and negative predictive values of CAT were 77% and 71%, respectively.

## Discussion

This study shows that FDG-PET represents a new procedure for the diagnosis of cancer of the pancreas and the periampullary region with a sensitivity higher than 90%. FDG-PET also proved most successful in the differentiation of pancreatic cancer from chronic pancreatitis, in particular if in the second group the pancreatic head region is enlarged. The specificity of FDG-PET within this group of patients was 88%.

Cancer of the pancreas still has a very poor prognosis, unless it is diagnosed at an early and resectable stage.[1-3 22] Our data show a relation between FDG accumulation and the size of the tumour. While all patients in advanced tumour stages (III–IV) had a focally increased accumulation in PET images, only five of eight patients in early stages showed increased FDG uptake.

Plasma glucose concentrations did not influence FDG uptake in the fasting state: standard uptake value and tumour/background ratio did not correlate with plasma glucose concentrations. Although there is evidence to suggest that diabetes mellitus may be responsible for false negative results,[14] none of the three FDG-PET negative patients with a malignant tumour in the pancreatic region suffered from diabetes mellitus. Moreover, the size of the tumour seems to limit the diagnostic accuracy in our series of patients, as all had a tumour of stages I or II. The value of this diagnostic procedure, however, in the detection of small

malignancies was not the aim of this study. Larger study populations will be required for a definite evaluation of FDG-PET in this respect.

The standard diagnostic procedures to diagnose pancreatic cancer are ultrasonography, CAT, and ERCP.[23–26] Ultrasonography represents the most widely used imaging procedure in patients presenting with a suspicious pancreatic mass.[23] However, the high percentage of inadequate results, the dependence upon experience of the investigator for satisfactory imaging, and its low sensitivity often require additional diagnostic procedures to be carried out. The ideal standard in the diagnosis of pancreatic cancer remains ERCP, which has accuracy rates of around 80–90%.[25 26] Only lesions that change the duct system, however, can be detected and often additional imaging procedures such as CAT are required to determine the size and the extent of the pancreatic lesion. The sensitivity of CAT to diagnose pancreatic cancer is between 50% and 90% and is based on an increase in pancreatic size, contour changes, obliteration of peripancreatic tissue or other signs of invasive or metastatic disease.[24] In addition, differential diagnosis between chronic pancreatitis and pancreatic cancer by CAT is extremely difficult.

In this study, the diagnosis of pancreatic cancer was based on functional changes in the pancreatic mass caused by tumour metabolism. This represents a new approach to the diagnosis of pancreatic malignancies. FDG-PET provides comparable diagnostic accuracy, but is less invasive than ERCP. In this series of patients its diagnostic accuracy in patients with histologically confirmed pancreatic carcinomas is definitely superior to CAT. The results of this investigation suggest a future complementary role of FDG-PET to other established techniques in the diagnosis of pancreatic cancer.

Our data support the recently published preliminary evidence of a high accuracy rate of PET in pancreatic cancer diagnosis.[13 14] The Aachen group had one of nine false positive PET results in chronic pancreatitis. Their false positive patient had previously undergone a BII resection.[14] In this study, four of 28 patients with histologically confirmed chronic pancreatitis had FDG accumulation in the pancreas. Patient history showed BII resection and thrombosis of the portal vein with venous hypertension, the placement of a nasobiliary probe, and haemorrhage into a pancreatic pseudocyst in three of these patients. Unspecific granulation tissue might have contributed to the false positive accumulation of FDG in the pancreatic region in these patients. Therefore, the specificity of FDG-PET seems to be limited (a) in patients with chronic pancreatitis who previously had upper gastrointestinal surgery, (b) if pancreatitis related complications that can lead to unspecific FDG accumulation (intracystic haemorrhage) have occurred, or (c) if interventional techniques (stent, probe placement) have been used.

Although it was not the aim of this study to evaluate FDG-PET as a diagnostic procedure for correct staging of pancreatic cancer, liver metastasis could be identified in seven of 17 patients with a stage IV tumour. Lymph node involvement was detected in three patients. As no histological verification of this metastasis was obtained, however, definite conclusions on the value of FDG-PET for staging pancreatic cancer cannot be drawn.

In the few patients investigated thus far, PET technology using FDG provided a sensitivity of >90% in patients suffering from breast, colonic, liver, or brain cancer, and lymphoma.[5–10] In our study, seven patients with pancreatic cancer that were negative by CAT showed FDG accumulation in the pancreatic tumour. In addition, three patients with pancreatic cancer in stage II could be detected by PET but not by CAT. Therefore, it seems probable that this technique might in the future contribute to the diagnosis of pancreatic cancer patients. The role of this technique, however, will be clearly defined in future larger oncological populations.

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